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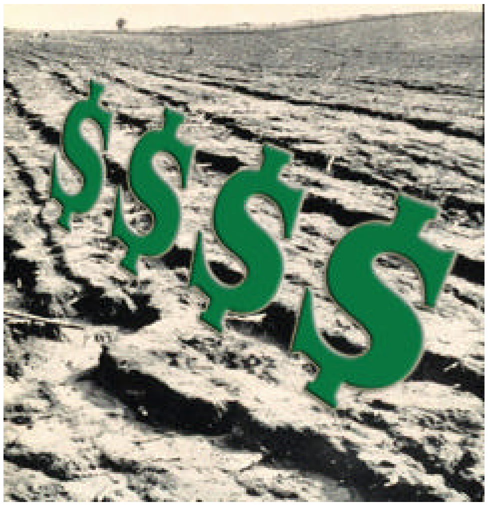
ECONOMIC IMPACTS OF DROUGHT AND THE BENEFITS OF NOAA's DROUGHT FORECASTING SERVICES



September 17, 2002 — Severe or extreme drought, as defined by the Palmer Drought Severity Index, has occurred in some portion of the United States every year from 1896 to 1995 (Knutson, 2001). Drought causes crop failure, wildfires, energy shortages, municipal water shortages, and fish and wildlife mortality, and, therefore, affects many sectors of the economy—namely agricultural, energy, and recreation industries, as well as municipalities, government and the environment. Average annual costs and losses in the United States due to drought are estimated at $6 to $8 billion. Flooding and hurricanes, though more publicized than drought, are responsible for only $5.9 billion and $5.1 billion in annual damages, respectively (according to NWS April 2002 Statistics). This article examines the economic impacts of drought in the United States and discusses how NOAA's drought forecasting services can reduce economic costs to individuals and society.

NOAA's Drought Forecasting Services
NOAA's drought forecasting services ease the impacts of drought — including economic impacts — by allowing people to take appropriate actions prior to onset. Specifically, NOAA's monthly U.S. Drought Outlook and U.S. Seasonal Drought Outlook provide valuable information about anticipated drought conditions across the United States:

- **U.S. Drought Outlook:** As a natural extension of the weekly U.S. Drought Monitor produced by NOAA, USDA, and the National Drought Mitigation Center, NOAA's Drought Outlook uses historical climate data and state-of-the-art computer model forecasts to help produce the nation's forecast for drought conditions.

- **U.S. Seasonal Drought Outlook:** NOAA's Climate Prediction Center issues the U.S. Seasonal Drought Outlook each month (on the second or third Thursday of the month at 3:15 p.m. ET, on the day it releases the long-lead temperature and precipitation outlooks). These outlooks depict general large-scale expectations of average conditions that are not specific to relatively small areas.

NOAA's advanced remote sensing capabilities — as well as the use of thousands of daily precipitation measurements — have greatly improved our ability to monitor and forecast drought. Drought forecasters also look at soil moisture conditions during past El Niño and La Niña events to help forecast soil moisture conditions if these phenomena are active or are predicted to form when the drought forecast is being prepared. Lastly, NOAA researchers are investigating possible correlations between drought and other variables, such as sea surface temperatures and atmospheric circulation features over various key areas in the Pacific and Atlantic oceans.

Economic Sectors Impacted by Drought

Agriculture
Agriculture is the largest consumer of water in the United States and, therefore, the most sensitive to drought. In fact, agriculture received nearly $8 billion in drought relief from the federal government during the mid-1970s drought, and more than $5 billion during the 1988-89 droughts (Wilhite, 1993). Crop and livestock producers incur a variety of revenue losses and cost increases during drought. For example, production costs increase if producers purchase supplemental water resources (e.g., drill a new well, lease water from senior water rights holders, shift to higher efficiency irrigation technologies) to support crops and livestock. Unfortunately, however, crop damage and/or herd reductions (and associated revenue loses) often occur, regardless of producers' attempts to acquire supplemental water.

Farmers and ranchers continue to suffer from drought impacts long after the disaster subsides. Drought-induced physiological stress increases a plant's susceptibility to disease and insects, and reduces perennial crop survival. Furthermore, wind erosion and the loss of soil organic matter can lessen cropland productivity for many years after a drought (Whitmore, 2000). Lastly, reduced crop quantity, quality and reproduction hinder a farmer's abilities to recover from drought. Livestock ranchers also suffer long-term impacts of drought. Decreased rangeland productivity forces ranchers to rest damaged grazing lands, lease additional graze lands (if available), increase supplemental feeding, and/or reduce herd size (Whitmore, 2000; Brown, 1986). Herd liquidation in response to drought often forces managers to sell during sub-optimal market conditions and reevaluate short- and long-term management plans (Brown, 1986).

Ironically, regional drought rarely disrupts agricultural output levels or revenue at the national level (Morehart et al., 1999). While commodity prices tend to rise in response to crop failure in drought-impacted areas, producers in un-impacted regions (or those holding inventories) benefit from national price increases (Whittaker, 1990). Therefore, regional level drought may have little impact on the overall viability of U.S. agriculture, although it does impose costs on regional and local agricultural economies. The 1999 drought, for example, led to farm net income losses of approximately $1.35 billion, with the hardest hit areas in the Northeast bearing 62 percent of these losses. Although farm net income losses only accounted for 3 percent of the expected national net farm income for that year; 25 percent of U.S. harvested cropland and 32 percent of pastureland were affected (Morehart et al., 1999). Because the demand and consumption of food products is largely fixed in the short run (i.e., inelastic), the immediate effect of drought is often passed on to consumers in the form of higher prices.

Producers can lessen the risk of economic damage from drought by maintaining inventories to sell during low yield years, when commodity prices are high. However, not all agricultural products are conducive to storage (e.g. milk). Likewise, inventoried livestock, is also not necessarily profitable during drought, because supply increases cause market prices to fall.

Crop and livestock insurance are also risk management tools for individual producers facing frequent or severe drought (See Morehart et al., 1999 for a brief example). Corn, soybean and wheat producers affected by the 1999 drought had insured 6 to 42 percent of their crop acreage at various coverage levels (Morehart et al., 1999). Although crop insurance can help reduce regional financial impacts of drought, not all producers can afford crop insurance coverage. Improved drought forecasting, as discussed later, will allow producers to better avoid regional financial "booms and busts" generated by drought.

Wildfire and Recreation

When combined with lightning strikes and human actions, drought produces thousands of wildfires in the United States each year. On average, more than $600 million was spent annually from 1994-2000 to fight an average 4.8 million acres of wildfire each year (NFIC, 2002). The federal government spends millions each year preventing and suppressing wildfires, and providing relief to those who incur fire damage. One of the worst fire seasons in recent U.S. history occurred in 2000; when more than 8.4 million acres of land was burned, costing the federal government $1.36 billion in fire suppression activities (National Interagency Fire Center, 2002). More than 6.4 million acres have burned already in 2002 (National Interagency Fire Center, 2002b), with several months left in the year.

Unfortunately, fire suppression efforts are not the only costs associated with drought-related wildfires – lives and valuable timber resources are lost, stream habitats are damaged by soil erosion and runoff from burned areas, livestock and wildlife are driven from their feeding grounds, and occasionally unique archaeological or natural land features are threatened. Likewise, insurance companies, homeowners and relief agencies incur damages to personal property. For example, the Cerro Grande wildfire in Los Alamos, New Mexico, required the evacuation of 18,000 residents, and burned or damaged nearly 250 homes. Six thousand insurance claims were filed as a result of this wildfire, costing insurers $70 million. Likewise, the Oakland/Berkeley Tunnel fire of 1991 destroyed 2,500 homes, causing $1.7 billion of insured damage and 25 deaths (Guidette, 2000). Unfortunately, the cost of residential damage from wildfire will continue to rise as communities expand farther into forested areas and the median cost of homes rise.

Reduced lake, reservoir and river levels, hamper boaters, swimmers, anglers, wildlife viewers and others' enjoyment of public and private resources (U.S. Army Corps of Engineers, 2000). For example, tourism in Yellowstone National Park came to an abrupt halt during the summer of 1988 (the driest summer in recorded history for the park) when 793,000 acres within the park (36 percent of the park's 2.2 million acres) and 400,000 additional acres in the Greater Yellowstone

Ecosystem burned (National Park Service, 2001). Although the federal government spent $120 million fighting these fires, a total of 67 structures were destroyed and property damage estimates approached $3 million (NPS 2001). Improved drought forecasting has many implications for wildfire prevention, short and long-term management, and damage mitigation. These implications will be discussed below.

Energy
Meeting energy demands during drought conditions is challenging. Not only do higher temperatures increase energy demand, but areas like the Pacific Northwest that rely on hydropower run an even greater risk of power shortages and increased energy prices.

Managing limited water resources for power generation involves building adequate reservoir water levels during the winter and spring when water is abundant, and stretching the water's use through the drought and high demand of summer. Furthermore, threatened and endangered salmon and steelhead species in much of the Pacific Northwest require water for their seasonal migration, thus limiting the availability of water for power generation. As a result, the federal government and hydroelectric plants are constantly working to find a balance between both hydropower and fish. NOAA's National Marine Fisheries Service, in its 2000 Biological Opinion on Hydropower Operations, recommended spring water-spills at dams and river flow for salmon and steelhead recovery efforts (Northwest Power Planning Council, 2001). Unfortunately, the summer of 2001 was one of the driest on record for the Northwest region, and hydropower agencies wrestled to find sufficient water for both fish and electricity generation. Ultimately, that balance led to a reduction in spring spill levels (at the expense of migrating salmon and steelhead), so power generation could continue through the summer to meet demands in California. Improved drought forecasting could help energy and fish managers allocate scarce water resources more efficiently by providing more accurate and advanced drought information. Energy consumers would also benefit from improved water management through more stable energy prices.

Municipalities
The importance of fresh drinking water becomes even more evident when drought strikes a major population center. The dry 2001-2002 winter, for example, resulted in 20 eastern states enforcing water restrictions by early spring. Drought emergencies were declared in New Hampshire, New Jersey, Maryland, New York, and Pennsylvania by April, as reservoir, groundwater and well levels remained precariously low (Baehrer, 2002).

Drought, combined with increasing urban development in arid regions, has forced cities to manage water resources more carefully. City, state and national drought plans are becoming much more common (Deister, 2001). Many municipalities, in addition to developing long-term drought plans, have also adopted proactive approaches to drought conditions. Water conservation and education programs, for example, actively encourage citizens to voluntarily use water-wise practices (e.g., using low-flow kitchen and bath fixtures and restricting water use for washing cars and outdoor landscaping). Businesses are encouraged to conserve water as well. Conservation is mandated (with fines of up to $1,000 for non-compliance) when water shortages become more severe (Baehrer, 2002).

Some cities buy water from agriculture and other cities to dampen the effects of drought. California's Department of Water Resources, for example, initiated a Dry Year Water Purchase Program for the year 2002 to help southern California cities purchase water from northern California. The program helped eight water agencies reduce water shortages by securing 140,000 acre-feet of water from other regions of California (American Water Works Association, 2002). Likewise, Las Vegas city officials now report needing $32 million to address current and future city water problems. Projects under consideration include increasing reservoir storage capacity, replacing leaky water pipes, and a new design for the city's dam system (U.S. Water News Online, 2002).

Water quality during drought is another concern for municipalities, since pollutants (i.e., chemicals and bacteria) become concentrated in smaller volumes of water that can be potentially harmful to human health. Restricting pollutant emissions and acquiring supplemental water resources and/or more reliable water sources are just a few of the ways of addressing water quality issues during drought.

Fish and Wildlife
Many fish and wildlife species are adversely affected by drought. Specifically, drought-induced increases in water temperature along with decreased dissolved oxygen levels can lead to fish crowding, stress, and death in lakes, ponds, rivers and streams (Texas Parks & Wildlife, 1998). As

mentioned previously, anadromous fish species (i.e., fish that spend all or part of their adult life in salt water and return to freshwater streams and rivers to spawn) that rely on water spills from dams during their seasonal migration must compete with hydroelectric energy demands for water resources, particularly during drought. Likewise, agriculture often takes precedence over wetlands in areas where the two share common water sources, thus forcing waterfowl and other bird species to seek alternative habitat.

The availability of aquatic habitat, drinking water, and food are major sources of stress for wildlife during drought. Wildlife often become more visible during drought as they try to survive the drought by expanding their range (often onto choice agricultural or residential lands) resulting in dangerous human-wildlife encounters (Colorado Division of Wildlife, 2002). It is not uncommon to find crop damage due to deer and elk, bear sifting through trash and mountain lions creeping through backyards during severe drought conditions. Prolonged drought conditions result in starvation, reduced reproductive success and recruitment, and susceptibility to disease that can severely affect wildlife populations for years. Drought-induced population impacts are economically costly. Reduced hunting and fishing success and viewing opportunities are a few examples of tangible economic losses resulting from drought's impact on wildlife.

Drought Forecast Improvements

Variability in annual water supply poses a challenge to many sectors of the economy, including farmers, public land and natural resource managers, hydroelectric producers, and municipalities. Improving the accuracy and lead-time of drought forecasts can ease the challenges decision makers face, lessen the economic losses due to drought and could even lead to economic benefits in a number of important sectors.

Agriculture
Long before weather events occur, agricultural producers need to decide, what type, where and how many acres of crops will be planted, and/or how many cattle will be sold, bought and bred. These decisions are based on a producer's practical knowledge of their land, capital resources, past decision-making experience and outcomes, and future weather and economic expectations. Given this information, farmers and ranchers make production decisions, which once instituted, are mostly irreversible due to the nature of crop and livestock production and markets.

Agricultural producers have limited time frames within which to make production decisions. Once they are made, farmers must passively endure the influence of many factors outside of their control, hoping their final choices pay off. Improved forecasting of drought onset, frequency, location and intensity would allow regional producers to make better choices. For example, given advanced notice regarding the onset, location and severity of a drought, producers could more accurately evaluate their production options. Drought resistant crops could be planted in lieu of traditional crops. Livestock producers (given advanced drought notice) could better time their herd sales, thus avoiding excess market supply, price decreases and associated profit losses. On a larger scale, improved drought forecasting could help producers nationwide prepare for the market impacts of drought (Glantz, 1982; Adams et al., 1995).

Wildfire and Recreation
Billions of dollars are spent each year preparing for and battling wildfires, with costs peaking during drought years. Long before wildfire season starts, millions of dollars are spent on fire prevention activities (i.e., forest health and fuel management). More advanced drought warnings and more accurate and detailed forecast information would improve public land managers' ability to maximize the effectiveness of limited fire management funds. Areas forecast to be at increased risk of severe drought during the next year, for example, could be targeted in advance with controlled burns (i.e., by manipulating fuel levels in forests prior to the occurrence of drought the costs of lightning strikes and human-caused fires can be reduced).

Severe fire seasons often strain federal agency resources and budgets. Firefighting resources could be more efficiently organized and more rapidly dispersed if drought forecasts offered more advanced and precise information. Quicker response times might reduce timber losses and property damage, which in turn reduce insurance claims and relief costs.

Energy
Hydroelectric companies could also benefit from improved drought forecasting, allowing them to better administer limited and variable water quantities over long time periods. Typically, winter storage is in preparation for summer use, with volume often set aside for water spills for fish. Because decisions made in one year influence the plant's power-generating abilities for the next

year (or more), more accurate and advanced drought notices would allow plant managers to make more informed production decisions regarding water storage needs and annual energy production schedules.

Likewise, water availability for spills and flow targeting could be confirmed farther in advance, thus giving fisheries managers more time to negotiate with hydroelectric facilities, or to seek supplemental water sources. Furthermore, improved drought forecasting should improve the electricity market's efficiency. Producers, anticipating future water shortages, could contract with other energy producers (non-hydro powered plants, or hydropower plants in non-drought regions) in advance, thus ensuring adequate power supplies at reasonable prices.

Municipalities

Like the energy industry, the primary challenge for municipalities during drought is securing water resources at a reasonable cost. Because supplemental water supplies are high during drought, advanced planning is critical. Improved drought forecasting would help municipalities prepare for drought. Water shortages, for example, could be averted by promoting conservation farther in advance, or by securing supplemental water resources before prices reached crisis-level highs. Reservoir levels could also be managed across a longer time frame, helping managers move toward a more efficient allocation of water resources through time.

Fish and Wildlife

Management of harvested fish and game species would benefit from improved drought forecasting, by allowing managers to adjust target population levels and harvest efforts during pre-drought years. Unintentional over-harvesting of game animals in the year preceding (or during) a drought can exacerbate the decline of already drought-stressed populations. With improved drought forecasts, managers expecting a drought next year could decrease harvest levels this year, to counteract high death rates during the drought. Alternatively, foreseeing habitat damage during drought at current population levels, managers could increase hunting or fishing efforts this year, in hopes of maintaining low, but robust game populations that will survive and recover from drought. Both of these management strategies could be applied to discrete populations (micromanagement), if the accuracy of drought forecasting were improved. Wildlife managers could circumvent drought-associated "booms and busts" in wildlife populations (and revenues from hunting and wildlife viewing), given the information offered by improved drought forecasts.

Threatened and endangered species management officials could also benefit from better drought forecasts. Preventing drought-related stress and death is particularly important considering the fact that water-reliant fish and bird species are so vulnerable to the impacts of drought and the loss of individual animals could be devastating to the future success of small populations. Advanced notice of an upcoming drought gives endangered species managers time to develop plans that will reduce the adverse effects of drought.

Another benefit to wildlife managers involves human-wildlife encounters as drought-stressed animals seek habitat, water and food. Little can be done to avoid the movement of animals into residential and agricultural areas during drought, but advanced warning can allow residents, farmers and wildlife officials to educate and prepare themselves for encounters and even avoid life threatening situations.

Conclusions

Drought impacts the economy in many ways. Agricultural communities face water shortages, crop failure and financial distress; hydroelectric-based energy companies face shortages in water used to both generate electricity and assist in the seasonal migration of fish; consumers face higher energy prices; wildfires damage property, impair stream habitat and reduce access to public lands. Water shortages force municipalities to restrict water use or purchase expensive supplemental sources, and fish and wildlife species struggle to find suitable habitat, water and food (often leading to dangerous and destructive encounters with humans). Millions in public expenditures are made each year fighting fires, rehabilitating public lands, and giving financial relief to drought and fire victims. Millions of private dollars are lost or redistributed through insurance claims, uninsured damage, farm revenue losses and gains, and impaired recreational opportunities. Although the cost of drought is a small proportion of output on a national scale (i.e., approximately $6 to 8 billion in average annual losses) (Knutson, 2001), its impacts can be devastating to local communities and economies. The economic costs of drought could be reduced if drought forecast improvements increase our ability to detect drought farther in advance, improved forecast accuracy, and increased the geographical detail of forecasts to pinpoint drought location, intensity and duration.

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NOAA's Climate Prediction Center

NOAA's monthly U.S. Drought Outlook

Weekly U.S. Drought Monitor

Advanced Hydrologic Prediction Service: Water Information for a Stronger and Safer America

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